VARIAN ASSOCIATES - BOMAC DIVISION
Salem Road
Beverly, Massachusetts

'64-5

# BL-221 70 Gc MAGNETRON PRODUCTION ENGINEERING MEASURE

SIXTH QUARTERLY PROGRESS REPORT
6 November 1962 to 6 February 1963

| | |
|---|---|
| CONTRACT NO: | DA-36-039-SC-85974 |
| CONTRACTING AGENCY: | U. S. Army Signal Supply Agency<br>225 South Eighteenth Street<br>Philadelphia 3, Pennsylvania |
| ATTENTION: | Contracting Officer<br>PEM and Facilities Procurement Branch<br>Procurement Management Division "C" |

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# BL-221 70 Gc MAGNETRON
# PRODUCTION ENGINEERING
# MEASURE
# SIXTH QUARTERLY PROGRESS REPORT

6 November 1963 to 6 February 1963

| | |
|---|---|
| OBJECT: | To investigate minor constructional modifications in the present design, evaluate a pre-production run of thirty (30) tubes and set up manufacturing facilities capable of producing fifty (50) tubes per month. |
| CONTRACT NO: | DA-36-039-SC-85974 |
| SIGNAL CORPS REQUIREMENTS: | SCS-70 dated 23 September 1959 |

Prepared by:

Gary G. Riska
Project Engineer, Power Tube
Product Development Group

Approved by:

Robert C. Sibley
Manager, Power Tube
Product Development Group

SIXTH QUARTERLY PROGRESS REPORT

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TEST DATA AND GRAPHS

## 2. ABSTRACT

The following work was done during this quarterly period.

a. Evaluation of a second lot of magnetrons made with anodes hobbed and machined in the Bomac facility.

b. Attainment of adequate frequency control on Bomac manufactured anodes.

c. Manufacture of a second hob using the hob grinder and associated facilities.

d. The investigation of tunability was completed with the conclusion that considerable development would be required to make it usable.

e. The humidity-temperature investigation was completed with the conclusion that the tube processing to be used will provide storage and use protection up to 100°F and 100% humidity environment.

f. The testing problem, which has been related to the high repetition frequency oscillation, has been resolved by modification of the test specification.

## 3. FACTUAL DATA

### 3.1 Continuation of Anode Manufacturing and Evaluation Program

Eight (8) more tubes with Bomac anodes were manufactured and tested during this quarterly period. Test data on these tubes is tabulated in Figure 1. This group of tubes exhibited closer control of the frequency parameter due to improvements in height control and tool sharpening methods during the maching of the anodes. The ability to maintain the same rake and cutting angle on resharpening is very important. Bomac is investing additional funds in tocl grinding equipment to achieve this consistency. Noticeable also in these tubes is the increase in leakage current. This is accounted for by the increase in cathode diameter used to lower the peak anode voltage which had been running near the high end of the specification and causing a decrease in yield. As the magnetic field is reduced on these larger cathode tubes the leakage current increases very rapidly and as a consequency th e power falls off. In spite of the pav problem, caused by the recalibration of the peak anode voltage circuit, the next tubes will be made with the smaller cathode diameter previously used. The recalibration resulted in an increase of pav readings of approximately 1400 volts. An increase of 700 volts was allowed in the specification. For a good production yield it is apparent that further modification will be required to properly center the operating point within the specified peak anode voltage range.

## 3. FACTUAL DATA

### 3.2 Tuner Investigation

In quarterly report number four it was pointed out that the need for frequency adjustment, to enable tubes to be made within the specified fixed frequency band, was not necessary due to expected improvements in anode machining technology. According to a request from the Signal Corp to pursue further the work done on tunability further tests were made on tuner model number two. It may be recalled that tuner Model #1 used an inductive plate covering two anode segments. Tuning range was too small. Tuner Model #2 uses an inductive tuning plate covering all of the anode segments. Frequency tuning from 67.5 Gc to 72.0 Gc was obtained on low level test with no mode cross overs and without apparent coupling problems, (see Figure 2A). A tube was completed to high power test. The tube was mody above a frequency of 70.15 Gc. From further low level measurements this moding appeared to be related to improved Q levels of the unwanted higher voltage mode. In addition to the onset of the moding condition it was apparent that the magnetic field needed to be increased as the frequency tuned higher in order to prevent the increase of leakage current. The magnets were not large enough to make the increase possible. It was also observed that power output decreased substantially as the frequency was tuned to the bottom limit of the available tuning

## 3. FACTUAL DATA

### 3.2 Tuner Investigation (cont'd.)

range. The reason for this has not been clearly defined.

It is generally apparent that a substantial development task is required to achieve tunability in this magnetron. Furthermore processing methods in use continue to provide magnetrons within the specified frequency band. Hence no further work is planned as part of this PEM Program.

### 3.3 Continuation of Humidity-Temperature Investigation of Exposed Tube Parts:

At the beginning of this quarterly period the temperature in the humidity chamber used for this study was increased from $100^{\circ}$F to $100^{\circ}$C. The relative humidity was maintained at 100%. The tubes which for nearly eight months had indicated no change or adverse effects with regard to internal tube pressure suffered a considerable increase in pressure within seventeen days under the new chamber conditions. Internal tube pressure increased from $3 \times 10^{-9}$ mmHg to $1 \times 10^{-3}$ mmHg for the gold plated tube; from $4 \times 10^{-9}$ mmHg to $1 \times 10^{-4}$ mmHg for the nickel plated tube and from $4.5 \times 10^{-9}$ mmHg to $5 \times 10^{-5}$ mmHg for the tube with heavier (+.0003") nickel plating before exhaust. Note Graph #3A on Page 20. Rust and/or corrosion on all these tubes was very severe as shown in Figure 3B on Page 21. Although ineffective

## 3. FACTUAL DATA

### 3.3 Continuation of Humidity-Temperature Investigation of Exposed Tube Parts (cont'd.)

at 100°C and 100% relative humidity Bomac will continue plating of tubes after the exhaust process as a safeguard against corrosion in storage environments up to 100°F and 100% relative humidity.

### 3.4 Grinding of a Second or Reserve Anode Hob in the New Hobbing Facility:

A second anode hob (B-3) was successfully ground in our new facility during this quarterly period. Two tubes #25 and #27 built with anodes hobbed with this hob were found satisfactory as can be seen in the data sheet, Figure 1, Page 17.

### 3.5 Revised Test Conditions:

In view of the delays experienced in the procurement of pulse transformers needed for the short pulse, high repetition frequency rate or Osc. (1) test conditions (tp= 0.03±0.0005 μsec. Du= 0.0005) and in compliance with the provisions of the contract as detailed under Note 5, Page 5 of Order No. 6029-PP-61-81-81, revisions proposed to the test specification SCS-70 were as follows:

I. Absolute Ratings:

| | Ef | epy | ib | pi | Pi | Du | tp | prr | tk | T |
|---|---|---|---|---|---|---|---|---|---|---|
| Units | V | kv | a | kw | W | | μs | pps | sec | °C |
| Maximum | 7.0 | 14.5 | 10.5 | 153 | 84 | .00055 | 0.33 | 17,000 | --- | 100 |
| Minimum | --- | --- | --- | --- | --- | --- | 0.03 | --- | 75 | --- |

Changed to:

| | Ef | epy | ib | pi | Pi | Du | tp | prr | tk | T |
|---|---|---|---|---|---|---|---|---|---|---|
| Maximum | 7.0 | 15.0 | 10.5 | 158 | 87 | .00055 | 0.30 | 17,000 | --- | 100 |
| Minimum | --- | --- | --- | --- | --- | --- | 0.025 | --- | 75 | --- |

II. Typical Operative Conditions:

| | If | ib | epy | tp | prr |
|---|---|---|---|---|---|
| Units | A | a | kv | μs | pps |
| Osc. (1) | 1.5 | 9.0 | 13.0 | 0.03 | 16,670 |
| Osc. (2) | 2.2 | 9.0 | 13.0 | 0.03 | 1,670 |

Changed to:

| | If | ib | epy | tp | prr |
|---|---|---|---|---|---|
| Osc. (1) | 1.5 | 9.0 | 13.3 | 0.03 | 10,000 |
| Osc. (2) | 2.0 | 9.0 | 13.3 | 0.07 | 7,150 |
| Osc. (3) | 2.2 | 9.0 | 13.3 | 0.25 | 2,000 |

III. Oscillation (1)

4.16.3.3 Pulse Conditions:

tp= 0.03 ± .005 μs

Du= 0.0005

**rrv= 400 kv/μs (max.)**

Changed to:

tp= 0.03 ± .005 μs

Du= 0.0003

rrv= 400 kv/μs (max.)

Note 6

4.16.3.4 Pulse Voltage:

epy: 12.0 kv to 13.50 kv

Changed to:

epy: 12.50 kv to 14.20 kv

4.16.3.5 Average Anode Current:

Note 1

Changed to:

Note 1 and Note 15.

Note 15 reading as follows: "The value of average anode current may be used as an approximate criteria. For more accurate evaluation of readings the value of peak current should be used.

4.16.3.6 **Power Output:**

**Po:** 5.00 watts minimum

<u>Changed to:</u>

**Po:** 3.00 watts minimum

4.16.3.7 **Spectrum Measurements:**

tp = 0.07 ± .01 μs

Du = 0.0003; ib = 9.0a

Notes 7, 8, 9

<u>Changed to:</u>

Deleted from Oscillation (1) test section and included in the new test section listed below.

IV. <u>4.16.3 Oscillation (2)</u>

New Test Section. Original SCS-70 Oscillation (2) test section presently listed as Oscillation (3) below.

$\sigma$ = 1.2:1.0 (max.)

except as otherwise noted

| | Test | | Sym. | Min. | Max. | Units |
|---|---|---|---|---|---|---|
| 4.16.3.2 | Heater-Cathode Warm-up Time: | Ef = 6.3V | tk | --- | 90 | sec's |
| | | Note 5 | | | | |
| 4.16.3.3 | Pulse Characteristics: | tp = 0.07 ± 0.01 μs | | | | |
| | | Du = 0.0005 | | | | |
| | | rrv = 300 kv/μs (max.) | | | | |
| | | Note 6 | | --- | --- | --- |

Osc. (2) cont'd

| | Test | | Sym | Min. | Max. | Units |
|---|---|---|---|---|---|---|
| 4.16.3.4 | Average Anode Current: | Ib= 4.5mAdc Note 15 | --- | --- | --- | |
| ------ | Peak Anode Current: | ib= 9.0a | --- | --- | --- | |
| 4.16.3.5 | Pulse Voltage: | --- | epy | 12.5 | 14.2 | kv |
| 4.16.3.6 | Power Output: | Within t= 100 sec's | Po | 5.0 | --- | W |
| 4.16.3.7 | Spectrum Measurement: | Notes 7, 8, 9 | | --- | --- | |
| ------- | Minor Lobes: | ----- | Ratio: | 8.0 | --- | db |
| ------ | R.F. Band-width: | ----- | B.W: | --- | $\frac{2.5}{tp}$ | Mc |
| ------ | Stability: | Note 10 | Missing pulses | --- | 1.0 | % |
| 4.16.5 | Pulling Factor: | ib= 9.0a Note 9 | $\Delta$F: | --- | 75 | Mc |
| 4.16.6 | **Pushing Factor: | ib= 8.0 to 9.0a | $\Delta$F: | --- | 5 | Mc/a |
| 4.10.7.3.1 | Fixed Tuned Frequency: | ib= 9.0a | F: | 69.0 | 70.5 | Gc |
| ------- | **Shelf Life Stability: | t= 90 days; Osc. (2); Notes 10, 11 | Missing pulse: | --- | 2.0 | % |

V. 4.16.3 Oscillation (3)--Formerly Osc. (2)

| | | Sym | Min. | Max. | Units |
|---|---|---|---|---|---|
| 4.16.3.3 | Pulse Characteristics: | | | | |
| | tp= 0.3 ± 0.03 µs: | | | | |
| | Du= 0.0005: | | | | |
| | rrv= 200 kv/µs (max.) | | | | |
| | Note 6 | --- | --- | --- | --- |
| Changed to: | | | | | |
| | tp= 0.25 ± 0.05 µs | | | | |
| | Du= 0.0005 | | | | |
| | rrv= 200 kv/µs (max.) | | | | |
| | Notes 6,14 | | | | |
| 4.16.3.4 | Average Anode Current: Ib= 4.5 mAdc | --- | --- | --- | --- |
| Changed to: | | | | | |
| | Ib= 4.5mAdc | --- | --- | --- | --- |
| | Note 15 | | | | |
| 4.16.3.5 | Pulse Voltage: --- | epy: | 12.0 | 13.5 | kv |
| Changed to: | --- | epy: | 12.5 | 14.2 | kv |

Osc. (3) cont'd

| | | | Sym. | Min. | Max. | Units |
|---|---|---|---|---|---|---|
| 4.16.3.7 | Spectrum Measurement: | Notes 7,8,9 | | | | |

Changed to:

Deleted from this test section.

Included in Osc. (2) test section.

| | | | | | | |
|---|---|---|---|---|---|---|
| ------ | Minor Lobes: | ------ | Ratio: | 8.0 | ---- | db |

Changed to:

Deleted from this test section.

Included in Osc. (2) test section.

| | | | | | | |
|---|---|---|---|---|---|---|
| ------ | R.F. Bandwidth: | ----- | BW: | --- | $\frac{2.5}{tp}$ | Mc |

Changed to:

Deleted from this test section.

Included in Osc. (2) test section.

| | | | | | | |
|---|---|---|---|---|---|---|
| ----- | **Stability: | Note 10 | MP | --- | 1.0 | % |

Changed to:

Deleted from this test section.

Included as a production measurement in Osc. (2) test section

| | | | | | | |
|---|---|---|---|---|---|---|
| 4.16.5 | Pulling Factor: | ib= 9.0a Note 9 | F: | --- | 75 | Mc |

Changed to:

Deleted from this test section.

Included in Osc. (2) test section.

Osc. (3) cont'd

| | | | Sym. | Min. | Max. | Units. |
|---|---|---|---|---|---|---|
| 4.16.6 | **Pushing Factor: | ib= 8.0 to 9.0a | F | --- | 5 | Mc/a |

Changed to:

Deleted from this test section.

Included in Osc. (2) test section.

| | | | | | | |
|---|---|---|---|---|---|---|
| 4.10.7.3 | Fixed tuned Frequency: | ib= 9.0 | F: | 69.0 | 70.5 | Gc |

Changed to:

Deleted from this test section.

Included in Osc. (2) test section.

------- **Shelf Life Stability:

t= 90 days

Osc. (2)

| | | | | |
|---|---|---|---|---|
| Notes 10,11 | MP: | --- | 2.0 | % |

Changed to:

Deleted from this test section.

Included in Osc. (2) test section.

V. Itermittent Life Test Operation

Life Test Cycle:

| Condition | Ib | Ef | Duration |
|---|---|---|---|
| Standby | --- | 6.3 | 3 Minutes |
| Osc. (1) | 4.5 mAdc | Note 5 | 18 " |
| Off | --- | 0.0V | 9 " |

Intermittent Life Test Operation, Cont'd

| | | | Sym. | Min. | Max. | Units |
|---|---|---|---|---|---|---|
| Changed to: | | | | | | |
| | Standby | | --- | | 6.3 | 3 Minutes |
| | Osc. (2) | | 4.5 mAdc | | Note 5,15 | 18 " |
| | Off | | --- | | 0.0V | 9 " |
| 4.11.4 | Cycling Life Test End Points: | --- | --- | --- | --- | --- |
| | Power Output: | Osc. (1) | Po: | 3.75 | --- | W |
| Changed to: | | | | | | |
| | Power Output: | Osc. (1) | Po: | 2.4 | --- | W |
| ----- | Frequency: | Osc. (1) | F: | 68.75 | 70.75 | Gc |
| Changed to: | | | | | | |
| | | Osc. (2) | F: | 68.75 | 70.75 | Gc |
| ----- | R.F. Bandwidth | Osc. (1) Notes 7,8,9,12 | BW: | --- | $\frac{3.5}{tp}$ | Mc |
| Changed to: | | | | | | |
| | | Osc. (2) Notes 7,8,9 | BW: | --- | $\frac{3.5}{tp}$ | Mc |
| ----- | Stability: | Osc. (1) Notes 7,8,9,12 | Missing Pulses: | -- | 2.0 | % |
| Changed to: | | | | | | |
| | | Osc. (1) Notes 9,10,13 | Missing Pulses: | -- | 2.0 | % |

| Intermittent Life Test Operation, (cont'd.) | | | Sym. | Min. | Max. | Units |
|---|---|---|---|---|---|---|
| ---- | Pulse Voltage: | Osc. (1) | epy: | 12.0 | 14.0 | kv |
| Changed to: | | | | | | |
| | | Osc. (1) | epy: | 12.5 | 14.6 | kv |
| | | Osc. (2) | epy: | 12.5 | 14.6 | kv |

## 4. CONCLUSIONS

### 4.1 Manufacture of Magnetrons with Bomac Anodes

Machining and deburring methods have been developed to the point where frequency control is adequate. The failure of the second lot of tubes to operate at the long pulse condition and the higher than normal leakage current evident in that lot of tubes shows that some design and processing problems still remain.

### 4.2 Tunability

Cold and hot test results indicate that a tuning range of about 2.5 Gc or about 3.5% is feasible. However, power output variation and mode instability was excessive and more development is required than is practical for this PEM program. Further anode manufacturing controls are now such that the specified frequency can be met without a frequency adjuster.

### 4.3 Temperature-Humidity Investigation

This investigation is now complete. For an environment of 100°F and 100% relative humidity any one of three tested processing methods will yield adequate protection, i.e., gold plating after exhaust, nickel

4.3 (continued)

plating after exhaust or heavier nickel plating before exhaust. Gold plating after exhaust has been chosen as the standard practice. None of the tested methods provided adequate protection for an environment of 100°C and 100% humidity.

## 5. PROGRAM FOR THE NEXT QUARTERLY PERIOD

5.1 Continuation of hob hobbed anode manufacturing and evaluation program with emphasis on improving the resonator or anode vane edges and thusly reduce to a minimum arcing between the anode and the cathode which was the cause of severe tube damage particularly under the long pulse condition (tp= 0.3μs, Du= 0.0005) testing.

5.2 Initiation of a program to acquire the necessary experience and know how for cold anode hobbing.

5.3 Investigation of the excessive leakage current problems experienced with the tubes built during this quarterly period.

5.4 Evaluation of Bomac anode tubes through shelf and operational life tests.

# BL-221
# TEST DATA
# FIGURE #1

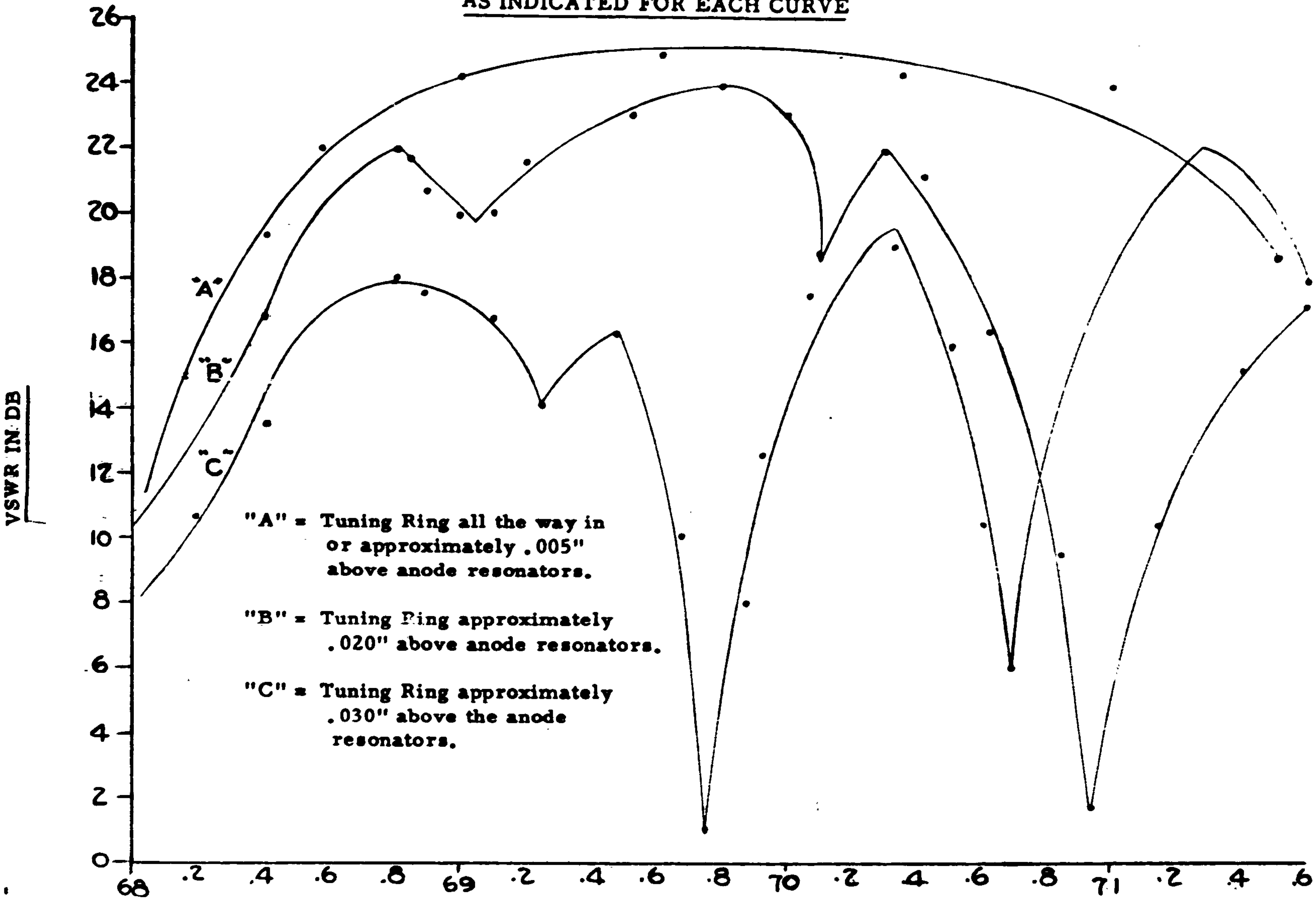
| TUBE NO. | TEST DATE | Heater Conditions | | | | Input Conditions | | | Output | | | Pulse Conditions | | | | Internal Tube Pressure (mmHg) | Anode Hob |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Starting | | Operating | | | | | | | | | | | | | |
| | | Eh (V) | Ih (A) | Eh (V) | Ih (A) | ib (A) | Ib (Ma) | epy (kv) | Po (W) | po (KW) | Fo (Gc) | tp (μsec's) | prf (pps) | du | Type Pulser | | |
| 18* | 12/28/62 | 6.3 | 2.6 | 2.7 | 1.1 | 9.0 | 6.0+ | 13.90 | 4.8* | 9.6* | 69.1 | 0.06 | 8,350 | 0.0005 | HTM | $1x10^{-8}$ | B-2 |
| 19* | 12/3/62 | 6.3 | 2.6 | 2.2 | 1.1 | 9.0 | 7.7+ | 13.30 | 4.6* | 9.2* | 69.4 | 0.07 | 7,150 | 0.0005 | HTM | $1x10^{-7}$ | B-2 |
| 20 | 1/8/63 | 6.3 | 2.5 | 2.7 | 1.1 | 9.0 | 7.7+ | 13.90 | 6.5 | 13.0 | 69.7 | 0.06 | 8,350 | 0.0005 | HTM | $1x10^{-8}$ | B-2 |
| 21 | 1/7/63 | 6.3 | 2.6 | 2.7 | 1.1 | 9.0 | 7.1+ | 13.40 | 6.5 | 13.0 | 69.3 | 0.06 | 8,350 | 0.0005 | HTM | $1x10^{-9}$ | B-2 |
| 25 | 1/23/63 | 6.3 | 2.5 | 2.7 | 1.1 | 9.0 | 6.0+ | 13.70 | 6.5 | 13.0 | 69.8 | 0.06 | 8,350 | 0.0005 | HTM | $1x10^{-9}$ | B-3 |
| 27 | 2/6/63 | 6.3 | 2.6 | 2.7 | 1.1 | 9.0 | 6.6+ | 13.60 | 5.2 | 10.4 | 70.05 | 0.05 | 8,350 | 0.0005 | HTM | $1x10^{-8}$ | B-3 |
| 30 | 2/4/63 | 6.3 | 2.5 | 2.7 | 1.1 | 9.0 | 5.1 | 13.50 | 5.7 | 11.4 | 69.90 | 0.06 | 8,350 | 0.0005 | HTM | $1x10^{-8}$ | B-2 |
| 31 | 2/5/63 | 6.3 | 2.6 | This tube went to air during aging due to the development of a leak in the Vac-Ion Pump system. | | | | | | | | | | | | | |

*Out of spec tubes for power output--minimum spec limit is 5 watts (10 kw)

+Higher average anode current attributed to inadequate shielding and slightly larger emitter diameter used.

BL-221

TUBE RESONANCE WITH TUNER POSITION AS INDICATED FOR EACH CURVE




FREQUENCY IN Gc

FIGURE 2A

BL-221
TUNEABLE MAGNETRON

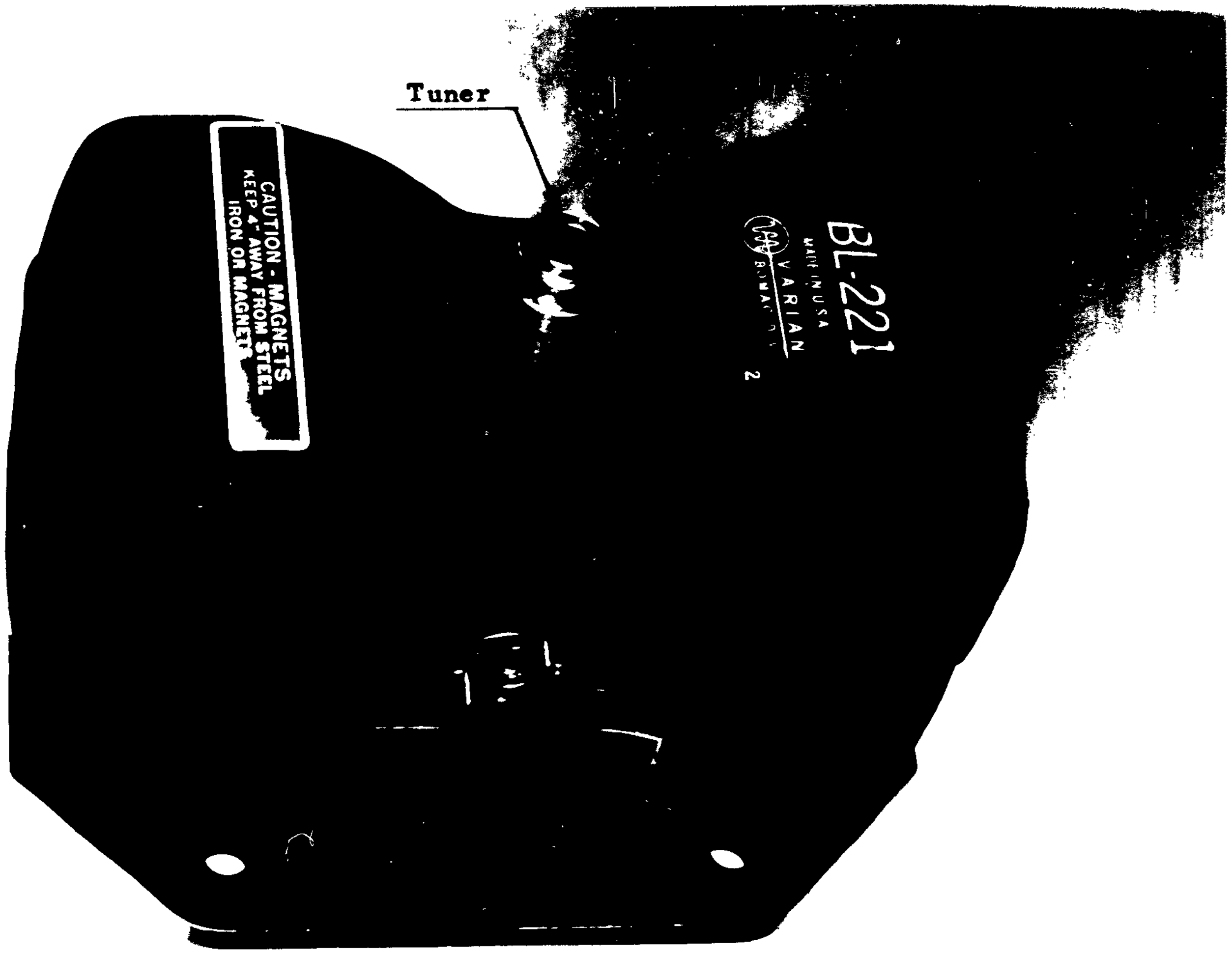
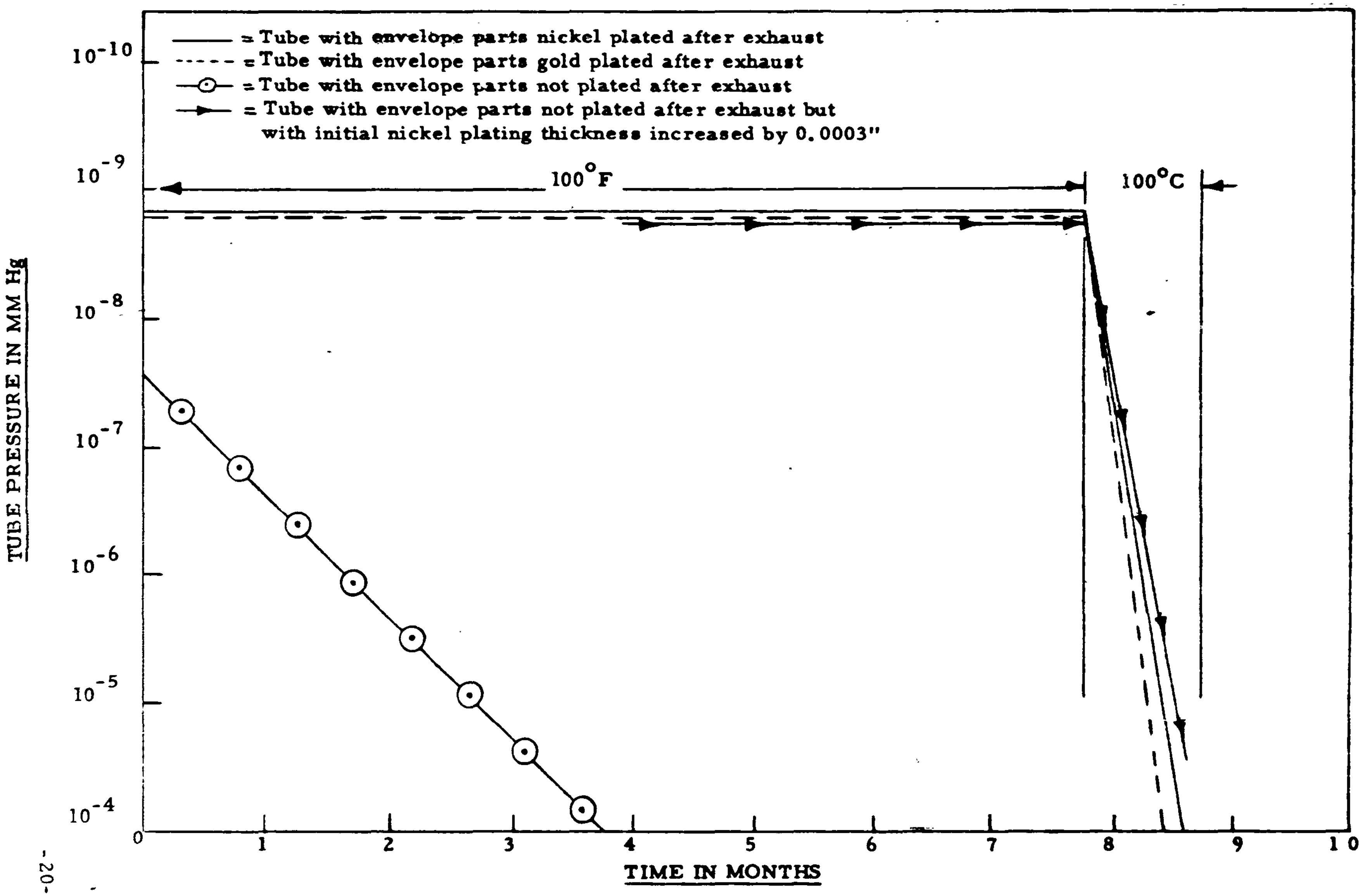



FIGURE #2B

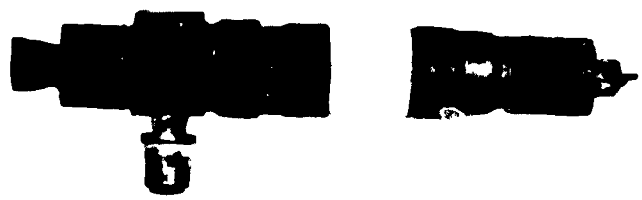
## BL-221
## HUMIDITY CHAMBER TESTS

Relative Humidity: 100%
Temperature: As indicated on the graph

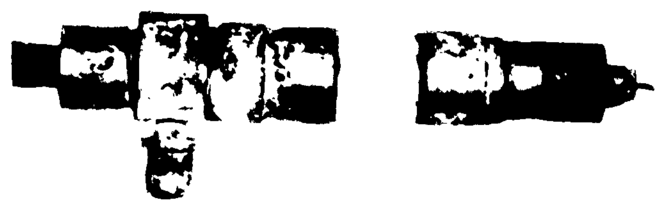


BL-221

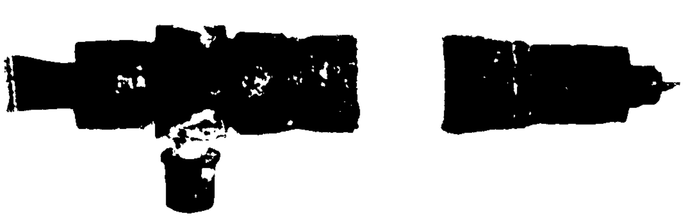
MAGNETRONS (BODIES) AFTER EXPOSURE
TO HUMIDITY CHAMBER
TESTS



Tube with nickel plating
after exhaust



Tube with Gold plating
after exhaust



Tube with heavier nickel plated
parts before exhaust

FIGURE #3B

## 6. INTRODUCTION OF THE NEW TECHNICAL AND ADMINISTRATIVE PERSONNEL

6.1 Robert C. Sibley, Manager of Power Tube Product Development.

Mr. Sibley received his Bachelor degree in Electrical Engineering from Rensselaer Polytechnic Institute in Troy, New York, in January 1951 and his Masters degree from Northeastern University Evening School in 1958. He worked as a Magnetron Development Engineer for Sylvania Electric Products from 1951 to 1954, and then supervised similar activity from 1954 to 1955. During part of 1955 and 1956 he was Project Engineer on M type Carcinotrons in the advanced Development Group. Early in 1957 he was temporarily assigned to organize a Product Development Group on Ferrite Isolators and Coaxial TR tubes. From 1957 through 1962 he was the Engineering Supervisor and Section Head of Sylvania's Product lines at Williamsport, Pa., including magnetrons, M type carcinotrons, TR tubes, planar triodes, BWO's, gas switching and mounting tubes, and gas display tubes. Mr. Sibley served as chairman of the Crossed Field Device Committee of the EIA Engineering Council for about three years. Since January of 1963 Mr. Sibley has been Manager of Product Development for Bomac's Power Tube Division.

6.2 L.M. Vant--Chief Test Engineer

Mr. Vant received his Bachelor Degree in Electrical Engineering from Northeastern University, Boston, Mass. in June 1932. He successfully completed ESMWT course in electronics at Northeastern University in 1943. He is registered as a Professional Engineer in Massachusetts. Mr. Vant was employed by Raytheon Mfg. Co. of Newton, Mass., as a Laboratory Assistant from 1934 to 1937, and X-ray Engineer by Picker X-Ray Co., from 1937 to 1943. From 1943 to 1951 he was employed as a Junior and later as a Senior Engineer in the Magnetron Development Laboratory at Raytheon Mfg. Co., Waltham, Mass. His responsibilities included the development of microwave plumbing for magnetron testing and the testing of development magnetrons. During 1951 to 1954 he was employed at Diamond Mfg. Co., of Wakefield, Mass. as an engineer responsible for the design of coaxial R. F. Connectors and microwave components. In 1954 Mr. Vant joined Bomac Laboratories, Inc., as an Engineering Specialist. He was first responsible for the testing of development magnetrons and procurement of the necessary test equipment. His next assignment was the responsibility for the design, procurement and manufacture of electron tube test equipment for the plant. Later he was responsible for the development of microwave plumbing components. Mr. Vant's most recent assignment has been that of Chief Test Engineer in the Power Tube Group with responsibility for the testing of development magnetrons, the development and procurement of magnetron test equipment and the development, manufacture, and maintenance of magnetron test plumbing for the group.

## MAN-HOURS OF WORK PERFORMED

| | | |
|---|---|---|
| 1. | R. C. Sibley, Manager | 56.0* |
| 2. | R.S. Briggs, Sr. Scientist | 24.0* |
| 3. | Leslie M. Vant, Chief Test Engineer | 72.0* |
| 4. | Gary G. Riska, Project Engineer | 189.5 |
| 5. | Alan P. Waterman, Test Equipment Design Constructions | 3.0 |
| 6. | Miscellaneous: This Catagory includes all other man hours expended on the program in such areas as testing, processing, assembly work, drafting, incoming material inspection, test equipment work and maintenance, anode manufacturing, etc., etc. | 934.5 |
| | Total time expended | 1271.00 |

*This time falls under the general company overhead Category and is not added as a direct charge. It is included here however, to indicate total effort and attention devoted to the BL221 Project by Bomac